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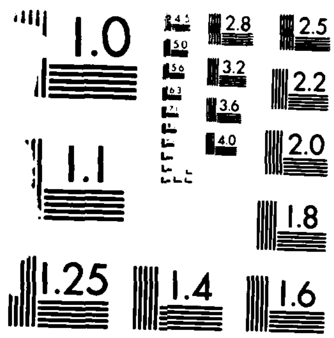
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DEPARTMENT OF BIOLOGICAL SCIENCES
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THE SEASONAL PHYTOPLANKTON ASSEMBLAGES ASSOCIATED WITH THE CHESAPEAKE BAY PLUME AND WATERS OFF DAM NECK, VIRGINIA

By

Harold G. Marshall, Principal Investigator

Final Report
For the period ending December 1984

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Under
Contract DACW65-81-C-0051
Work Order No. 19

US Army Corps
Of Engineers
Norfolk District

February 1985

Report B- 45

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A165332

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release, distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) B-45
6a. NAME OF PERFORMING ORGANIZATION Old Dominion University, Dept. of Biological Sciences 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U.S. Army Corps of Engineers, Norfolk District
6c. ADDRESS (City, State, and ZIP Code) Norfolk, VA 23508	7b. ADDRESS (City, State, and ZIP Code) Norfolk, Virginia 23510-1096
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Corps of Engineers, Norfolk District 8b. OFFICE SYMBOL (If applicable) NAOPL; NAOEN	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DACW65-81-C-0051
8c. ADDRESS (City, State, and ZIP Code) Norfolk, Virginia 23510-1096	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
The Seasonal Phytoplankton Assemblages Associated With the Chesapeake Bay Plume and Waters Off Dam Neck, Virginia

12. PERSONAL AUTHOR(S)
Marshall, H.G.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ____ TO ____	1985, February	24

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Chesapeake Bay plume, phytoplankton. seasonal composition, growth periods, influencing factors, temperature, salinity, nutrients, population dynamics

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The coastal waters south of the Chesapeake Bay entrance contain a diverse assemblage of phytoplankters, dominated by net and nanoplankton components. Two major growth periods occur in later winter-spring and fall, and coincide with rising and decreasing water temperatures and changes in available light, rainfall, salinities, among other factors.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Craig L. Seltzer	22b. TELEPHONE (Include Area Code) (804) 441-3767/827-3767 22c. OFFICE SYMBOL NAOPL-R

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508

FEB. ~~May~~ 1985

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By

Harold G. Marshall
Department of Biological Sciences
Old Dominion University
Norfolk, Virginia 23508

In a recent two year phytoplankton study of the lower Chesapeake Bay, Marshall and Lacouture (1985) noted the major growth periods were dominated by a diatomaceous flora and a pico-nanoplankton complex <10 μM that was mainly composed of cyanobacteria and chlorophytes. The trend for maximum concentrations during spring and fall persisted, with numerous pulses common throughout each year. Distinction between the phytoplankton assemblages within the Chesapeake Bay and the coastal waters outside the Bay have been noted by Marshall (1980, 1982). In collections taken during March, June, and October, the extent of the Bay plume could be identified by the composition differences of the phytoplankton assemblages within the plume and those from the shelf waters. It was also noted that the pattern of plume development and the time period that the plume's identity could be maintained varied. This was apparently under the influence of a variety of factors that contributed to making this section of the middle Atlantic Bight both dynamic and productive. These factors include a variety of current and counter currents over the shelf that have a net southern flow, but there is also a sursurface and westward drift of shelf water across the middle and outer shelf (Allen et al., 1983). In addition, there are tidal currents in and out of the Bay, the passage of the Bay plume southward along the Virginia coast and the influence of major storms, upwelling, and prevailing wind patterns. Productivity for this region is high, and is given as 310 $gCm^{-2}yr^{-1}$ by O'Reilly and Busch (1984).

The purpose of this study was to provide a seasonal profile of the phytoplankton composition from this coastal region where there is a diverse represen-

tation of estuarine and shelf populations. The phytoplankton will be characterized in relation to both net and pico-nanoplankton categories, with general comparisons made to assemblages characteristic to the lower Chesapeake Bay and waters of the continental shelf.

METHODS

Monthly collections were taken at the surface and a depth one meter above the bottom at five stations, located off Cape Henry and wouthward along the Virginia coast (Figure 1). Standard hydro water bottle casts were used to obtain 500 ml water samples that were preserved with buffered formalin. Replicate samples were taken at two stations, with Lugols solution used as the preservative. A settling and siphoning procedure followed to obtain a 20 ml concentrate that was transferred to a settling chamber for examination with an inverted planktion microscope. The entire sample was scanned at X125 for counts of the larger net species. A random field and minimum count basis was used at X315 for microplankton and at X500 for pico-nanoplankton, to obtain an 85% accuracy estimate for these two categories. Occasional samples were processed for examination with a scanning electron microscope. Cell volume (biomass) measurements were determined by approximating the shape of each species to one or more geometrical forms, obtaining mean measurements of the cells, and determining the cell volume in μM^3. Collections were made from November 1983 through September 1984. Salinity values and other station data were provided by personnel from the ODU Applied Marine Research Laboratory.

RESULTS

Mean salinity and temperature values for surface and bottom collections are given in Figure 2. The surface salinities exhibited the greater variation and range (20.0 to 30.2 $^{o}/oo$) during the sampling, with lowest values associated with

late spring. The bottom water salinities were more consistent throughout the year, having a range of 27.8 to 31.1 °/oo. Highest water temperatures were associated with late summer and early fall, with lowest temperatures occurring in January. Seasonal temperature patterns were similar for the two depths with the largest difference in July when the mean surface and bottom temperatures were 17.1 and 12.5 °C, respectively.

A total of 276 phytoplankters were identified in this study (Table 1). They consisted of Bacillariophyceae (165), Dinophyceae (71), Haptophyceae (8), Cyanobacteria (5), Euglenophyceae (5), Chlorophyceae (11), Prasinophyceae (2), Chrysophyceae (6), Cryptophyceae (2) and Xanthophyceae (1). In addition, there were high concentrations of a pico-nanoplankton component composed mainly of an unidentified group of cyanobacteria and chlorophyceae species, and microflagellates. These were placed into size categories of <3, 3-5, and 6-10 μM. These consisted of round, oval, and irregularly shaped cells. The most numerous group was the <3 μM size class, followed by cells 3-5 μM in size.

The five sampling stations may be geographically divided into three groups. Station 10 is located directly east of Cape Henry with a water depth of 20-22 M, and is the station with closest proximity to the Chesapeake Bay entrance. Stations 12 and 13 are located nearest to the Virginia shoreline where water depth is 10-12 M. Offshore, in deeper water (17-18 M), are stations 1 and 11. Similarities in phytoplankton composition are also found in stations 12 and 13, and in 1 and 11. Because of these similarities, these two station sets will be frequently referred to as the near and far shore stations, with the Bay entrance station being number 10.

The total phytoplankton exhibited similar patterns of seasonal development at all the stations. The collections began during a decline period that followed a major fall development in 1983. Low concentrations came in winter with numbers rising during spring, declining in summer, to rise again in fall (Figures 3,4,5).

A more consistent growth pattern was associated with the entrance and near shore stations, with the highest concentrations found along the near shore (Figures 3-5). Off shore, the maxima were not as great, but there were additional pulses in late winter and summer. The significance of the net and pico-nanoplankton to these counts is given in Figure 3, which indicates that portion of the total count that is composed of net phytoplankton. Their maxima are not as pronounced, with the main growth occurring in spring, with similar concentrations at both depths. These net species were mainly diatoms, and to a lesser extent a dinoflagellate assemblage. The pico-nanoplankton component responsible for these major seasonal expressions was composed of single celled, small (<3 μM) cyanobacteria and a variety of other cells consisting mostly of chlorophyceans and microflagellates inthe 3-5 μM size range. The composition of the pico-nanoplankton appeared stable, with mainly changes in the magnitude of cell concentrations the major difference. More seasonal variation in composition was associated with the microflagellates and net plankton.

Phytoplankton biomass is depicted in this study by cell volume concentrations with these values given for the five stations in Figures 6, 7, and 8. The seasonal patterns generally mimic cell concentrations, showing fall and spring maxima interspaced with winter and summer minima. However, these patterns tend to be more graphic and minimize the importance of some nanoplankton fluctuations. Surface and bottom values are more similar during fall, summer, and winter. Distinct, but varied differences are most common in spring and are generally the products of different growth expressions by developing species. Overall, there are more phytoplankton cells and biomass in this area during the spring months than at other times during the year.

Winter Composition

Winter concentrations are low, coinciding with a period of population decline

and lowest seasonal temperatures. Early winter was characterized by net phytoplankton dominated by diatoms. These included *Coscinodiscus oculis iridis*, *C. gigas*, *C. concinnus*, *C. asteromphalus*, *Chaetoceros danicum*, *C. diadema*, *Cerataulina pelagica*, *Bacteriastrum varians*, and several *Cocconeis* spp. In midwinter a combination of small, chain-forming diatoms and mostly larger diatoms predominated. They included *Leptocylindrus danicus*, *Rhizosolenia delicatula*, *R. alata*, *R. calcar avis*, *R. imbricata*, and *R. stolterfothii*. This period coincided with the beginning of the vernal growth period. Other cells characteristic of the vernal outburst became dominant between mid and late winter, with *Skeletonema costatum*, *Rhizosolenia setigera*, and *Rhizosolenia fragilissima*. the main components of this group. Later species included *Leptocylindrus minimus*, *Nitzschia pungens*, *Ditylum brightwelli*, *Thalassiosira nordenskioldii*, and *Thalassionema nitzschioides*, and a small *Thalassiosira* sp. At the close of winter, several dinoflagellate were becoming more abundant, including *Dinophysis punctata*, *Prorocentrum minimum*, and *Protoperidinium breve*. Other more common forms included *Chlorella* sp., *Emiliania huxleyi*, and a variety of dinoflagellate cysts. The pico-nanoplankton were ubiquitous. The vertical distribution of diatoms during winter was more homogeneous at the Bay entrance and near shore stations with a tendency for higher concentrations in the bottom samples, and higher numbers near shore (Figures 9-11). Off shore the spring peaks were similar in time, but less in magnitude, with higher numbers at the surface during the spring growth, but generally reversed at other times. In contrast, the dinoflagellates more frequently had higher concentrations at the surface throughout the year, with the exception of summer (Figures 9,12,13).

Spring Composition

Spring is associated with the months of March, April, and May, in addition to rising water temperatures, less saline surface waters, and longer periods of daylight. The small sized, chain-forming diatoms that were dominant in late

winter maintained increased growth levels and dominance into early spring. This was the period of maximum diatom development. The major species were *Skeletonema costatum, Rhizosolenia fragilissima, Leptocylindrus danicus, L. minimus, Thalassiosira nordenskioldii, Thalassionema nitzschioides, Rhizosolenia alata,* and *Nitzschia pungens.* Other prominent cells at this time included *Asterionella glacialis, Corethron criophilum, Cylindrotheca closterium, Cerataulina pelagica, Ditylum brightwellii, Rhizosolenia setigera, and R. calcar avis. Prorocentrum minimum and Protoperidinium breve* remained common, with the dinoflagellates gradually becoming more abundant. *Ceratium tripos, Ceratium longipes, Ceratium lineatum, Ceratium fusus, Heterocapsa triquetra, Gonyaulax polyedra,* and *Amphidinium acutissima* were also common. Highest dinoflagellate levels were at the entrance station throughout the year. Other prominent forms were *Emiliania huxleyi, Chlorella* sp., *Cryptomonas* sp. and rising levels of chrysophyceans. This last group was mainly represented by *Calycomonas ovalis* and *C. wulfii.* The pico-nanoplankton were also abundant reaching peaks in late spring. There was also a modest pulse of the euglenoid *Trachelomonas intermedia* at station 11 with a general increase in numbers of cyanobacteria. Coccolithophores were very patchy, often absent at some stations, but very abundant at others (e.g. Station 11).

Summer Composition

The decline of the spring diatom outburst coincided with the coming of summer and the beginning of the dinoflagellate summer maximum. Water temperatures and surface salinity continue to rise, with offshore waters beginning to stratify. This summer diatom flora was a mixture of species influenced by several successional transitions. Remnants of the spring diatom outburst persisted into early summer and remained dominant at some stations (e.g. *Skeletonema costatum, Leptocylindrus danicus, Nitzschia pungens*). *Cyclotella caspia* and several unidentified centrales (<10 uM) were also very abundant. This latter group apparently contained small *Thalassiosira* spp. and possibly other *Cyclotella* spp. However, the overall

drop in diatom abundance takes place at all the stations. The dinoflagellate maximum persists through a summer period that would be characterized as a seasonal low for the total phytoplankton. A diverse representation develops, becoming more prominent as the concentrations of other cells decline. Prominent forms include *Amphidinium* spp., *Ceratium* spp., *Dinophysis* spp., *Gonyaulax* spp., *Prorocentrum* spp., and *Protoperidinium* spp. More specifically, *Prorocentrum micans*, *Cryptomonas* sp., and *Calycomonas wulfii* were well distributed and abundant during this period. During mid and late summer, many of the larger centrales became more abundant (e.g. *Rhizosolenia calcar avis*, *R. imbricata*), but toward the end of this period pockets of small sized chain-forming diatoms were more evident.

Fall Composition

Highest surface water temperatures occurred in early fall (25.9 °C) in association with rising salinity values. The collections were limited to separate sampling periods from the beginning of fall (1984) and its termination (1983), so coverage over a continuous three month period was not possible in this study. However, the trends noted here of a rising population in early fall followed by a decrease into winter is similar to earlier patterns noted in the lower Chesapeake Bay (Marshall, 1967, 1980, 1982; Marshall and Lacouture, 1985). Dominant cells were similar to those noted for the spring outburst. These included *Skeletonema costatum*, *Leptocylindrus danicus*, *Rhizosolenia setigera*, and *Thalassiosira nordenskioldii*. Remnants from the summer flora included *Chaetoceros compressus*, *C. decipiens*, *Cerataulina pelagica*, in addition to several *Rhizosolenia* spp. and *Coscinodiscus* spp. Many of these larger cells became abundant in late fall, with their abundance complementing the decrease in the smaller diatoms. Early fall also contained high concentrations of the Chlorophyceans and Prasinophytes. Other prominent species included *Emiliania huxleyi*, *Prorocentrum minimum*, and the pico-nanoplankton component (<3 μM).

DISCUSSION

The coastal waters directly south of the Chesapeake Bay entrance contain a diverse assemblage of phytoplankters dominated by net and nanoplankton components. Seasonal expressions of cell number are greatly influenced by the high concentrations of pico-nanoplankton populations which excel in numbers, yet still mimic the growth patterns for many of the net species. The two major growth periods occur in late winter-spring and fall, and coincide with rising and decreasing water temperatures and changes in available light, rainfall, salinities, among other environmental conditions. An exception to this pattern is associated with the dinoflagellate maximum that is common to summer, at the time when the total phytoplankton concentrations are in a minimal period of growth. Within the lower Bay, earlier studies have noted more of a sequential series of multiple seasonal pulses, that are overlayed by basically a general trend for the bimodal spring-fall maxima (Patten et al., 1963; Marshall, 1967, 1982; Marshall and Lacouture, 1985). In contrast, shelf studies within the area indicate the more classical bimodal pattern, but containing considerable patchiness where various pulses and mini-successional patterns may be found (Marshall, 1984a, 1984b; Marshall and Cohn, 1985). This region under study is influenced by both systems. Water from the Bay plume changes intra-seasonally in its composition, quantity of flow, temperature, and salinity. No doubt there are other variables of change that would influence the phytoplankton composition, including among others, water quality, nutrient concentrations and the influenceof changing weather related events. Although the lower Bay contains a characteristic core assemblage of species, there are numerous opportunist species that will develop and vary annually in their contributions to the Bay flora and its plume. The same opportunity is present in the shelf waters, but fluctuations in environmental factors and biotic development would tend to be less pronounced. In this region where the shelf and Bay waters meet, there is a tendency for mixed population to occur, and for high cell con-

centrations to prevail as they continue to be closely associated with regional seasonal patterns for spring-fall maxima.

The species within these samples represented a mixture of both shelf and estuarine types. However, the dominant species, such as *Skeletonema costatum* and *Leptocylindrus danicus*, among others, are ubiquitous dominants for the northeast coast, in other major estuaries in this region, and at sites along the outer continental shelf (Marshall, 1984a). These are not unique for the area, nor are the various assemblages seasonally noted within this study. However, the importance of this total flora to local fisheries and the benthic community should be significant. For instance, a selective preference based on the size of the phytoplanktor has been noted by several investigators. Turner et al. (1983) related seasonal food chains of micro-herbivores to feeding on the nanoplankters (e.g. copepod larvae, copepodites), with net plankton the more common food for adult copepods and fish larvae. In Monterey Bay, Garrison (1975) associated the reduction of nanoplankton to selective grazing by microzooplankton and planktotrophic larvae, and horizontal advection out of area. Capriulo and Carpenter (1983) found nanoplankton, with sizes less than 10 µM a common food for tintinnids in Long Island Sound. They noted high densities of nanoplankton associated with, but not dependent of seasonally high concentrations of tintinnids. Fritz et al. (1984) also noted in laboratory feeding experiments that oyster larvae selected small phytoplankters (<10 µM) over larger celled forms from natural estuarine assemblages. Similar findings were reported for oyster larvae by Mauer et al. (1984), whereas Pierson (1983) found the Bay scallops preferred larger cells. The preference for phytoplankton cells larger than 10 µM was reported for planktonic copepods (Mullin and Brooks, 1967) and by anchovy larvae (Scura and Jerde, 1977). Grazing patterns of the Atlantic menhaden also indicate a preference for plankton greater than a 13 to 16 µM minimum size (Durbin and Durbin, 1975). These studies indicate the trophic relevance for both major size categories of the phytoplankton to various faunal components of a region.

ACKNOWLEDGEMENTS

Appreciation is given to personnel from the Old Dominion University Applied Marine Research Laboratory for collecting the samples and for the salinity determination. Special thanks is given to graduate research assistants Richard Lacouture and Dorothy A. Randolph for their contributions in sample analysis and data compilation. This study was supported by the Norfolk Division of the U.S. Army Corps of Engineers.

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Table I. Phytoplankton observed during this study. Seasonal presence noted with X. Dominant species are indicated by A, B, C, in order of decreasing abundance.

BACILLARIOPHYCEAE	W	S	S	F
Achnanthes sp.	-	-	-	X
Achnanthes fimbriata (Grunow) Ross	X	-	-	-
Achnanthes lemmermann Hustedt	X	-	-	-
Actinoptychus senarius Ehrenberg	X	X	X	X
Amphiprora sp.	X	X	X	-
Amphiprora gigantea v. sulcata (O'Meara) Cleve	X	-	-	-
Amphora sp.	X	X	X	X
Amphora coffeaeformis (Agardh) Kutzing	X	-	-	-
Amphora crassa Gregory	X	-	-	-
Asterio lampra van Heurckii Brun	X	-	-	-
Asterionella bleakeleyi Smith	X	-	-	-
Asterionella formosa Hassall	-	X	-	-
Asterionella glacialis castracane	X	B	X	X
Asterionella notata (Grunow) Grunow	X	-	-	-
Bacillaria paxillifer (Muller) Hendey	-	-	-	X
Bacteriastrum sp.	X	-	-	-
Bacteriastrum varians Lauder	X	-	-	-
Bellochea horologicalis von Stosch	X	X	X	-
Biddulphia sp.	X	-	-	X
Biddulphia alternans (Bailey) van Heurck	X	X	X	X
Biddulphia aurita (Lyngbye) Brebisson	-	X	-	-
Biddulphia granulata roper	-	X	-	-
Biddulphia mobiliensis (Bailey) Grunow	-	-	X	X
Biddulphia pulchella Gray	X	-	-	-
Biddulphia tridens (Ehrenberg) Ehrenberg	X	-	-	-
Caloneis sp.	-	X	-	-
Caloneis staurophora (Grunow) Cleve	X	-	-	-
Caloneis wardii Cleve	X	-	-	-
Campylosira cymbelliformis (Schmidt) Grunow	-	X	-	-
Cerataulina pelagica (Cleve) Hendey	C	C	C	X
Chaetoceros sp.	X	X	X	X
Chaetoceros affine Lauder	-	-	-	X
Chaetoceros atlanticum Cleve	X	-	-	-
Chaetoceros breve Schutt	X	-	-	-
Chaetoceros coarctatum Lauder	X	-	-	-
Chaetoceros compressum Lauder	-	X	X	X
Chaetoceros concavicorne Mangin	X	-	-	X
Chaetoceros constrictum Gran	-	-	-	X
Chaetoceros curvisetum Cleve	-	-	X	X
Chaetoceros danicum Cleve	X	X	X	X
Chaetoceros debile Cleve	X	X	-	X
Chaetoceros decipiens Cleve	-	X	X	X
Chaetoceros densum Cleve	X	-	-	-
Chaetoceros diadema (Ehrenberg) Gran	X	-	-	-
Chaetoceros didymus v. protuberans (Lauder) Gran	X	-	-	-
Chaetoceros diversum Cleve	X	-	-	-
Chaetoceros muelleri Lemmerman	X	-	-	-
Chaetoceros neogracile van Langingham	X	-	X	X

	W	S	S	F
Chaetoceros pendulum Karsten	X	X	X	X
Chaetoceros pseudocurvisetum Mangin	X	-	-	X
Chaetoceros rostratus Lauder	X	-	-	-
Chaetoceros tetrastichon Cleve	X	-	-	-
Chaetoceros sociale Lauder	-	X	X	-
Chaetoceros subtile Cleve	X	-	X	-
Climacodium sp.	X	-	-	-
Climacodium frauenfeldianum Grunow	X	-	-	X
Cocconeis sp.	-	-	X	-
Cocconeis distans Gregory	X	-	-	-
Cocconeis molesta v. crucifera Grunow	X	-	-	-
Cocconeis pinnata Gregory	X	-	-	-
Cocconeis scutellum Ehrenberg	X	-	-	-
Cocconeis scutellum v. ornata Grunow	X	-	-	-
Corethron criophilum Castacane	X	C	X	-
Coscinodiscus sp.	X	X	X	X
Coscinodiscus asteromphalus Ehrenberg	X	-	-	-
Coscinodiscus concinnus Smith	X	-	-	-
Coscinodiscus gigas v. praetexta (Janasch) Hustedt	X	-	-	-
Coscinodiscus granulosus Grunow	X	-	-	-
Coscinodiscus marginatus Ehrenberg	-	-	-	X
Coscinodiscus obscuris Schmidt	X	-	-	-
Coscinodiscus oculus iridis Ehrenberg	X	X	X	X
Coscinodiscus perforatus Ehrenberg	X	-	-	-
Cosconodiscus radiatus Ehrenberg	-	-	-	X
Coscinodiscus tabularis Grunow	X	-	-	-
Coscinodiscus wailesii Gran et Angst	-	-	X	-
Coscinosira polychorda (Gran) Gran	-	X	X	X
Cylindrotheca closterium (Ehrenberg) Reimann et Lewin	X	C	C	X
Cyclotella sp.	-	X	X	-
Cyclotella caspia Grunow	C	X	B	X
Cyclotella glomerata Bachmann	-	X	-	-
Cyclotella meneghiniana Kutzing	X	-	-	-
Cyclotella striata (Kutzing) Grunow	-	X	-	-
Cyclotella stylorum Brightwell	X	-	-	-
Cymbella sp.	X	-	-	-
Dactyliosolen antarcticus Castracane	X	-	-	-
Dactyliosolen mediterraneus Peragallo	-	-	X	-
Diploneis sp.	X	X	X	X
Ditylum brightwelli (West) Grunow	X	C	X	X
Eucampia zoodiacus Ehrenberg	-	-	X	X
Fragilaria sp.	X	-	-	-
Grammatophora sp.	X	X	X	-
Guinardia flaccida (Castracane) Peragallo	X	X	X	X
Gyrosigma sp.	X	-	-	-
Gyrosigma fasciola (Ehrenberg) Cleve	X	X	-	X
Hantzschia marina (Donkin) Grunow	X	-	-	-
Hemiaulus indicus Karsten	X	-	-	-
Hemiaulus sinensis Greville	-	-	-	X
Hemidiscus cuneiformis Wallich	X	-	-	-
Leptocylindrus danicus Cleve	B	C	A	C
Leptocylindrus minimus Gran	C	B	X	X
Licmophora sp.	X	-	X	-
Lithodesmium sp.	X	-	-	-
Lithodesmium undulatum Ehrenberg	-	X	-	-

	W	S	S	F
Melosira sp.	-	-	X	-
Navicula sp. #1	-	X	X	-
Navicula sp. #2	-	-	X	-
Navicula arenaria Donkin	-	-	-	X
Navicula cancellata Donkin	-	X	-	-
Navicula maculata (Bailey) Edwards	X	-	-	-
Navicula paleralis (Brebisson) Smith	X	-	-	-
Nitzschia sp.	-	-	X	-
Nitzschia clausii Hantzsch	X	-	-	-
Nitzschia delicatissima Cleve	-	-	X	-
Nitzschia longissima (Brebisson) Ralfs	X	X	-	-
Nitzschia lorenziana Grunow	X	-	-	-
Nitzschia pacifica Cupp	X	-	-	-
Nitzschia pungens Grunow	C	C	B	X
Nitzschia seriata Cleve	X	X	-	-
Nitzschia spathulata Brebisson	X	-	-	-
Nitzschia socialus Ralfs	X	-	-	-
Pinnularia sp.	-	-	X	-
Paralia sulcata (Ehrenberg) Cleve	X	X	X	X
Plagiogramma sp.	-	X	-	-
Plagiogramma interruptum (Gregory) Ralfs	X	-	-	-
Plagiogramma staurophorum (Gregory) Heilberg	-	-	X	-
Plagiogramma van Heurckii Grunow	-	-	-	X
Pleurosigma sp.	X	X	X	X
Pleurosigma angulatum (Quekett) Smith	X	X	X	X
Pleurosigma angulatum v. strigosa (Smith) van Heurck	X	-	-	-
Pleurosigma delicatulum Smith	X	-	-	-
Pleurosigma elongatum Smith	-	-	X	-
Raphoneis sp.	X	X	-	-
Raphoneis amphiceros Ehrenberg	X	X	X	X
Raphoneis surirella Grunow	X	X	X	X
Rhizosolenia sp.	-	X	-	-
Rhizosolenia alata Brightwell	B	B	X	X
Rhizosolenia alata f. gracillima (Cleve) Grunow	C	-	X	X
Rhizosolenia alata f. indica (Paragallo) Gran	C	-	-	X
Rhizosolenia calcar-avis Schultz	C	C	X	X
Rhizosolenia delicatula Cleve	B	C	X	X
Rhizosolenia fragilissima Bergon	C	B	X	X
Rhizosolenia herbetata f. semispina (Hensen) Gran	X	X	X	X
Rhizosolenia imbricata Brightwell	C	X	X	X
Rhizosolenia setigera Brightwell	C	C	X	C
Rhizosolenia stolterfothii Peragallo	C	X	-	X
Rhizosolenia styliformis Brightwell	X	-	-	-
Schroederella delicatula (Peragallo) Pavillard	X	X	X	X
Skeletonema costatum (Greville) Cleve	B	A	C	A
Stephanopyxis turris (Greville) Ralfs	-	-	-	-
Stauroneis sp.	X	-	-	-
Streptotheca thamensis Shrubsole	-	-	X	X
Synedra sp.	-	-	X	-
Synedra tabulata (Agardh) Kutzing	X	-	-	-
Synedrosphenia gomphonema (Janisch) Hustedt	-	-	X	X
Tabellaria fenestrata (Lyngbye) Kutzing	-	-	X	-
Thalassionema nitzschioides Hustedt	C	C	C	X
Thalassiosira sp.	X	X	X	X
Thalassiosira decipiens (Grunow) Jorgensen	X	C	X	X

	W	S	S	F
Thalassiosira eccentrica (Ehrenberg) Cleve	X	X	X	X
Thalassiosira gravida Cleve	X	-	-	X
Thalassiosira nordenskioldii Cleve	X	C	-	C
Thalassiosira pseudonana (Hustedt) Hasle et Heimdal	X	-	-	-
Thalassiosira rotula Meunier	X	X	-	-
Thalassiosira oestrupii v. venrickae Fryxell et Begin	-	X	X	X
Thalassiothrix sp.	X	-	-	-
Triceratium sp.	X	-	X	-
Unidentified pennate diatoms <20 µm	X	X	X	X
Unidentified pennate diatoms >20 µm	X	X	X	X
Unidentified centric diatoms <20 µm	C	-	-	-
Unidentified centric diatoms >20 µm	X	X	X	X

DINOPHYCEAE

Amphidinium sp.	-	-	X	-
Amphidinium acutissimum Schiller	-	X	X	-
Amphidinium acutum Lohmann	-	X	X	X
Amphidinium crassum Lohmann	-	X	-	-
Amphidinium schroederi Schiller	-	-	X	-
Ceratium contrarium (Gourret) Pavillard	X	-	-	-
Ceratium fusus (Ehrenberg) Dukardin	X	X	C	X
Ceratium lineatum (Ehrenberg) Cleve	X	X	X	X
Ceratium longipes (Bailey) Gran	-	-	X	X
Ceratium macroceros (Ehrenberg) van Hoffen	-	-	-	X
Ceratium massiliense (Gourret) Jorgensen	X	-	-	X
Ceratium minutum Jorgensen	-	-	X	-
Ceratium pavillardii Jorgensen	X	-	-	-
Ceratium tripos (Muller) Nitzsch	X	X	X	X
Cladopyxis setifera Lomann	-	-	X	-
Cystodinium sp.				
Dinophysis sp.	X	X	X	X
Dinophysis acuminata Claparede et Lachmann	-	-	-	X
Dinophysis acuta Ehrenberg				X
Dinophysis caudata Kent	X			X
Dinophysis diegensis Kofoid				
Dinophysis fortii Pavillard	X	-	X	-
Dinophysis hastata Stein			X	
Dinophysis norvegica Claparede et Lachmann	X	X	X	X
Dinophysis ovum Schutt	X		X	
Dinophysis punctata Jorgensen	X	X	X	X
Diplopsalis lenticula Bergh	X	-	-	-
Diplopeltopsis minor (Paulsen) Pavillard	-	-	X	-
Glenodinium sp.	X	-	-	-
Glenodinium gymnodinium Pen. rd	X	-	-	-
Gonyaulax apiculata (Penard) Entz	X	-	-	-
Gonyaulax diacantha (Meunier) Schiller	-	-	X	-
Gonyaulax diegensis Kofoid	-	-	-	X
Gonyaulax digitalis (Pouchet) Kofoid	-	-	X	X
Gonyaulax spinifera (Claparede et Lachmann) Diesing	=	-	X	X
Gonyaulax tricantha Jorgensen	-	-	X	-
Gymnodinium sp.	C	X	X	X
Gymnodinium nelsonii Martin	-	-	X	X

	W	S	S	F
Gyrodinium sp.	X	X	X	X
Heterocapsa triquetra (Ehrenberg) Stein	X	X	X	-
Katodinium rotundatum (Lohmann) Loeblich	X	-	X	-
Oxytoxum sp.	-	-	X	-
Oxytoxum sceptrum (Stein) Schroder	X	-	-	-
Podolampas bipes Stein	X	-	-	-
Prorocentrum sp.	-	X	-	X
Prorocentrum compressum (Bailey) Abe	-	X	-	X
Prorocentrum micans Ehrenberg	X	X	C	X
Prorocentrum minimum (Pavillard) Schiller	C	B	X	B
Prorocentrum triestinum Schiller	C	X	X	-
Protoperidinium sp.	X	X	X	-
Protoperidinium bipes (Paulsen) Balech	-	X	-	-
Protoperidinium breve (Paulsen) Balech	X	C	X	X
Protoperidinium brevipes (Paulsen) Balech	X	X	X	X
Protoperidinium claudicans (Paulsen) Balech	-	-	-	X
Protoperidinium conicoides (Paulsen) Balech	-	-	-	X
Protoperidinium conicum (Gran) Balech	-	-	-	X
Protoperidinium depressum (Bailey) Balech	-	-	X	X
Protoperidinium diabolim (Cleve) Balech	-	-	X	-
Protoperidinium divergens (Ehrenberg) Balech	X	-	X	-
Protoperidinium globulum (Stein) Balech	X	-	-	-
Protoperidinium granii (Ostenfeld) Balech	X	X	X	X
Protoperidinium leonis (Pavillard) Balech	-	-	X	-
Protoperidinium oceanicum (Van Hoffen) Balech	X	X	X	X
Protoperidinium pallidum (Ostenfeld) Balech	-	X	-	-
Protoperidinium pellucidum Bergh	-	-	X	X
Protoperidinium pyriforme (Paulsen) Balech	-	-	X	X
Protoperidinium pentagonum (Gran) Balech	X	-	-	-
Protoperidinium sphaericum (Okamura) Balech	-	X	-	-
Protoperidinium steinii (Jorgensen) Balech	-	X	-	-
Pyrocystis lunula Schutt	X	-	-	-
Scrippsiella trochoidea (Stein) Loeblich	-	X	X	-
Unknown micro-flagellates	X	X	X	X
Unknown phytoflagellates	X	X	X	X
Dinoflagellate cysts	C	X	X	X

CHLOROPHYCEAE

	W	S	S	F
Ankistrodesmus falcatus (Corda) Ralfs	-	-	-	X
Chlorella sp.	C	C	C	C
Chlorella ellipsoidea Gerneck	-	X	-	-
Pediastrum simplex (Meyen) Lemmerman	X	X	X	X
Scenedesmus sp.	-	X	-	-
Scenedesmus armatus (Chodat) Smith	X	-	-	-
Scenedesmus acumin (Langerheim) Chodat	-	X	-	-
Scenedesmus quadricauda (Turpin) Brebisson	-	X	-	-
Staurastrum quadricuspidatum Turner	X	-	-	-
Tetraedron minimum (Braun) Hansgird	-	-	X	X
Tetraedron trigonum v. gracile (Reinsch) Detoni	X	-	-	-

	W	S	S	F
EUGLENOPHYCEAE				
Euglena sp.	-	-	X	-
Euglena acus Ehrenberg	X	-	X	X
Eutreptia lanowii Steuer	X	-	X	X
Eutreptia viridis Perty	X	-	X	X
Trachelomonas intermedia Dangeard				
XANTHOPHYCEAE				
Monodus guttula Pascher	X	-	-	-
HAPTOPHYCEAE				
Acanthoica acanthos Schiller	X	-	-	-
Calciosolenia granii Schiller	X	-	X	-
Cyclococcolithus leptoporus (Murray et Blackman) Kampt	X	-	-	-
Calyptrosphaera oblonga Lohmann	X	-	-	-
Emiliania huxleyi (Lohmann) Hay et Mohler	C	C	X	C
Ophiaster hydroides (Lohmann) Lohmann	-	-	X	-
Rhabdosphaera hispida Lohmann	-	-	X	-
Rhabdosphaera longistylis Schiller	-	-	X	-
Unknown coccolithophores	X	X	X	X
CYANOBACTERIA				
Anacystis aeruginosa Drouet et Daily	X	-	-	-
Gomphosphaeria aponina Kutzing	-	X	X	X
Nostoc commune Vaucher	-	-	X	X
Oscillatoria erythraea (Ehrenberg) Kutzing	X	X	-	-
Oscillatoria submembranacea Ardissone et Strafforella	X	-	-	-
Unknown cyanobacteria <3 μm	X	X	X	X
PRASIONOPHYCEAE				
Pyramimonas sp.	-	X	X	X
Pyramimonas torta Conrad et Kufferath	-	-	-	X
CRYPTOPHYCEAE				
Cryptomonas spp.	X	C	C	X
Chilomonas sp.	X	-	-	-

	W	S	S	F
CHRYSOPHYCEAE				
Calycomonas ovalis Wulff	-	C	X	-
Calycomonas wulfii Conrad et Kufferath	X	C	C	X
Dictyocha fibula Ehrenberg	-	X	-	-
Distephanus speculum (Ehrenberg) Haekel	-	X	X	X
Ochromonas minuscula Conrad	X	-	-	-
Olisthodiscus luteus Carter	X	-	X	X
Unidentified cells <3 µm	A	A	A	A
Unidentified cells 3-5 µm	C	X	X	X
Unidentified cells 6-10 µm	C	X	X	X

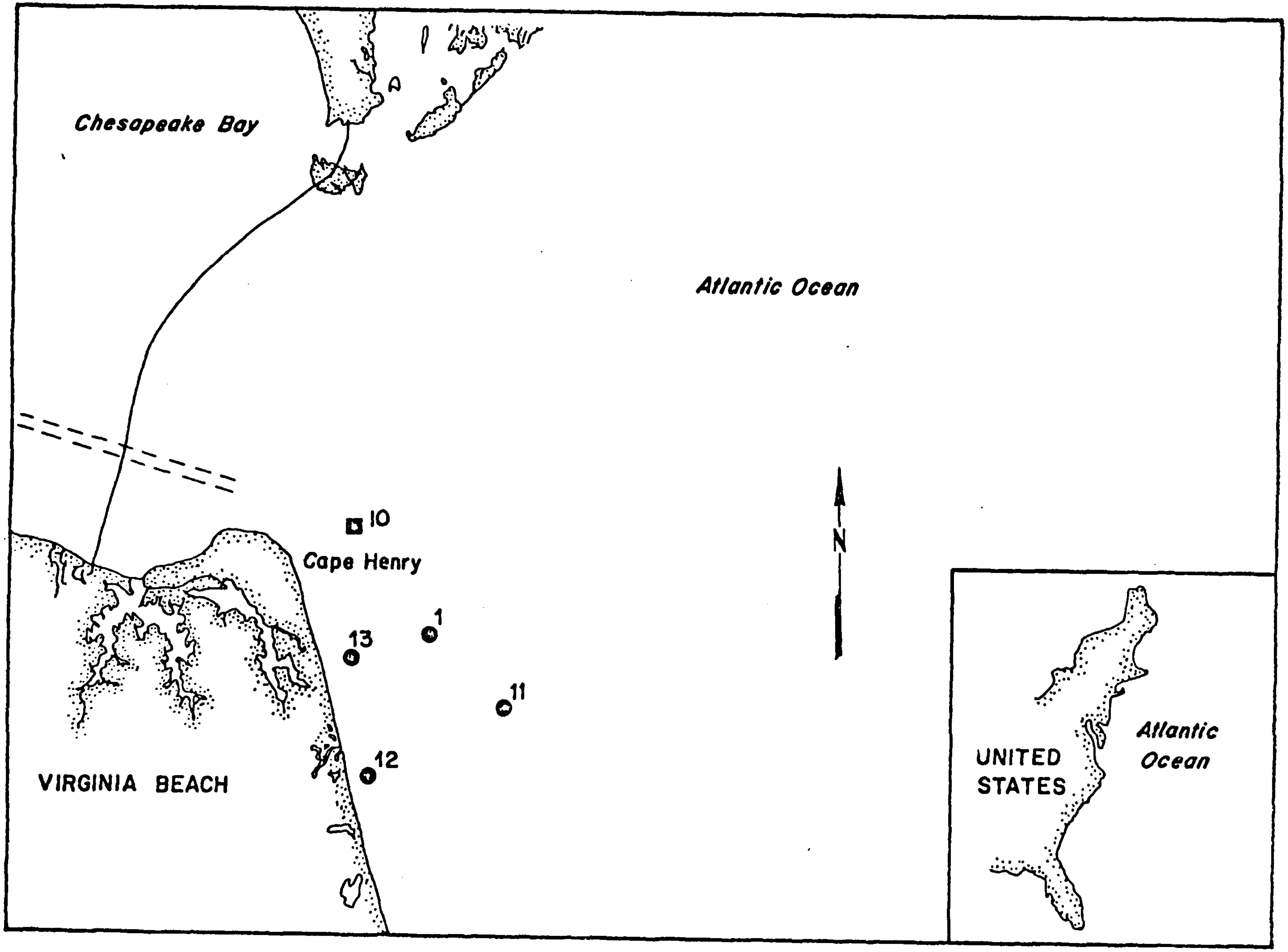


Figure 1. Station locations during the study.

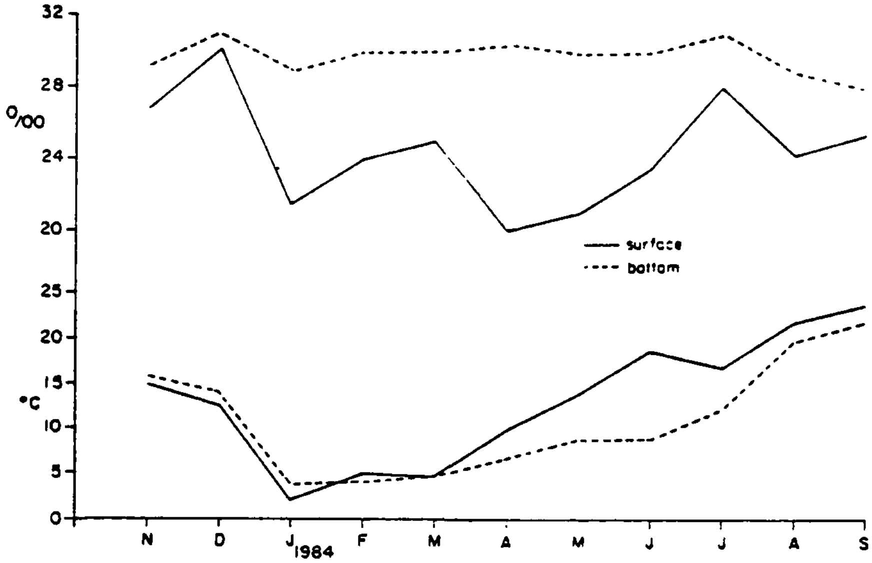


Figure 2. Salinity (°/oo) and temperature (°C) values for surface and bottom waters in the lower Chesapeake Bay.

Figure 3.

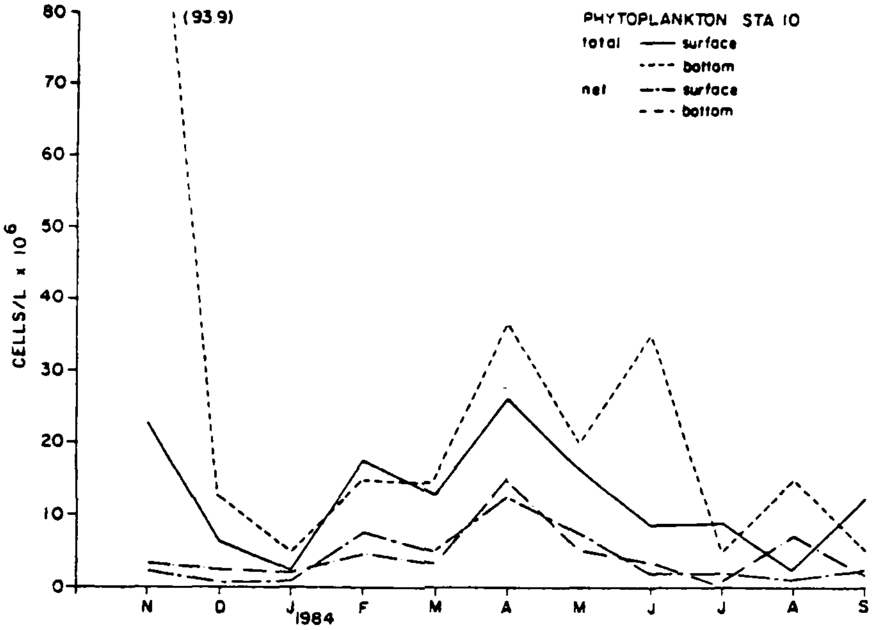


Figure 4.

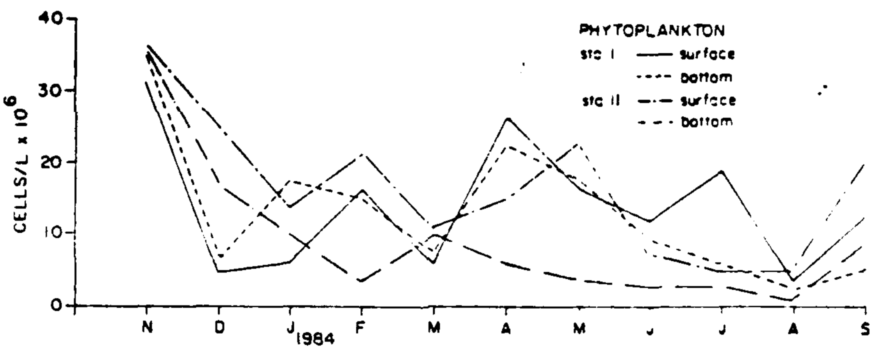
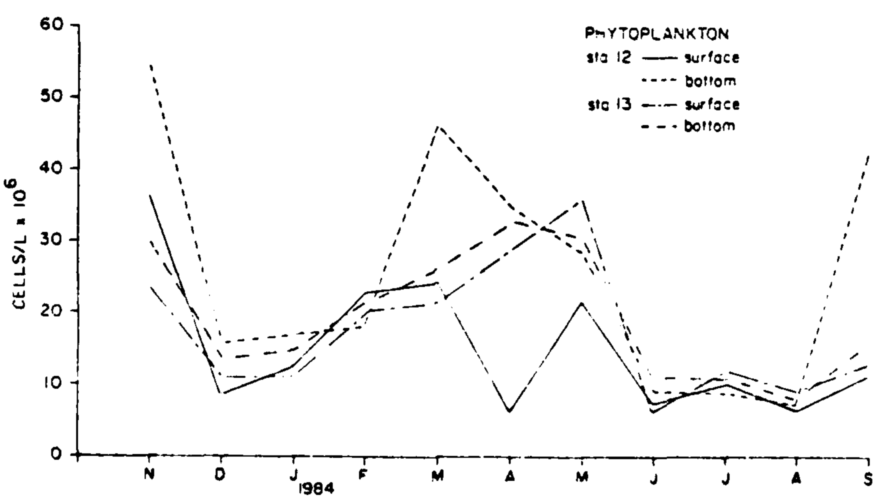


Figure 5.



Figures 3, 4, and 5. Total phytoplankton cell concentrations at stations in the study for surface and bottom waters. Net phytoplankton concentrations are also given for Figure 3.

Figure 6.

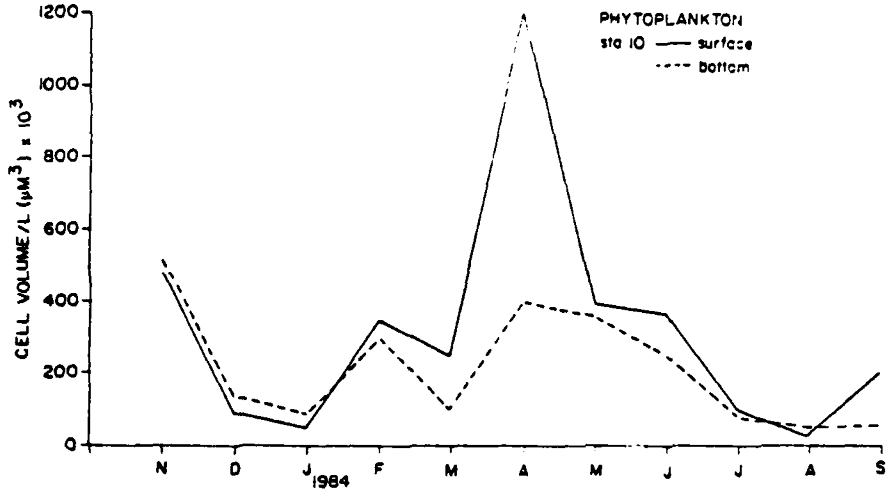


Figure 7.

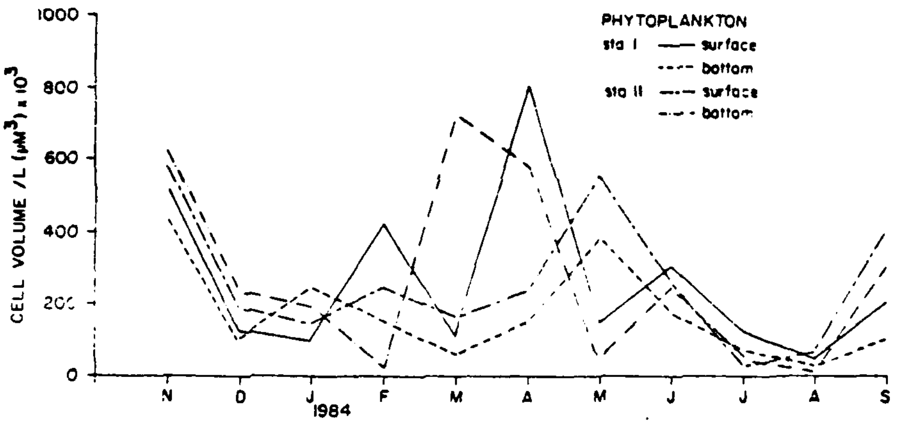
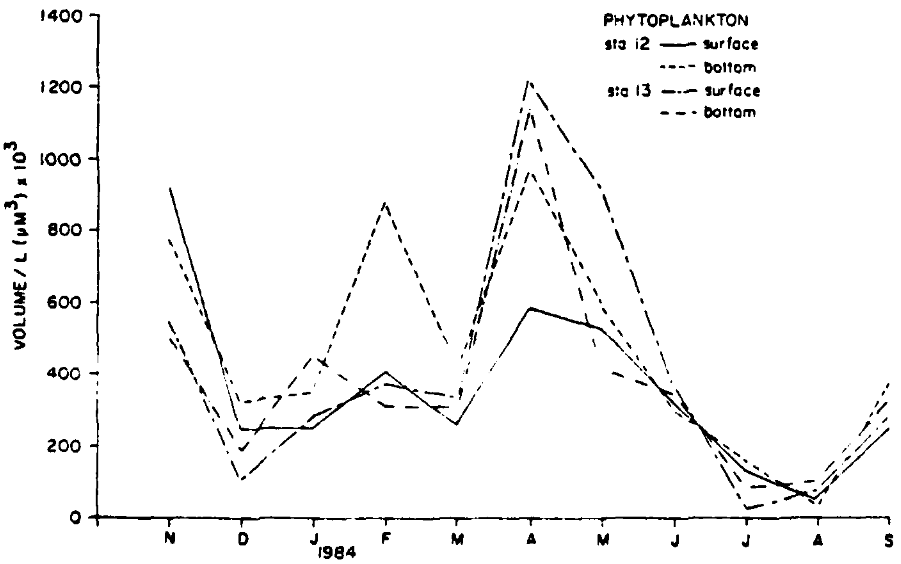


Figure 8.



Figures 6, 7, and 8. Total phytoplankton cell volume values at stations in the study for surface and bottom waters.

Figure 9.

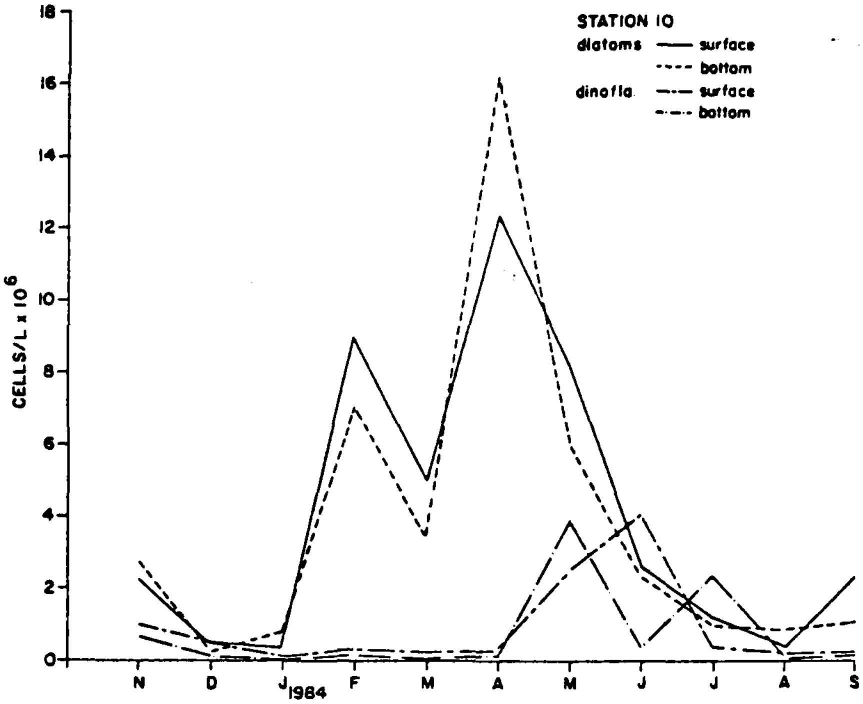


Figure 10.

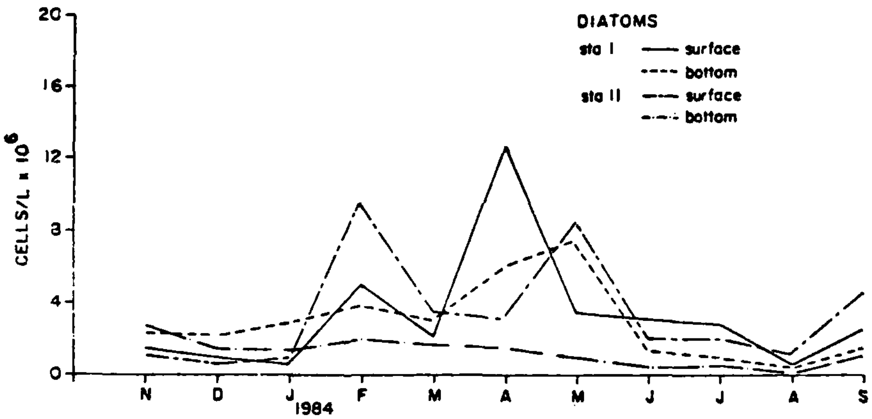
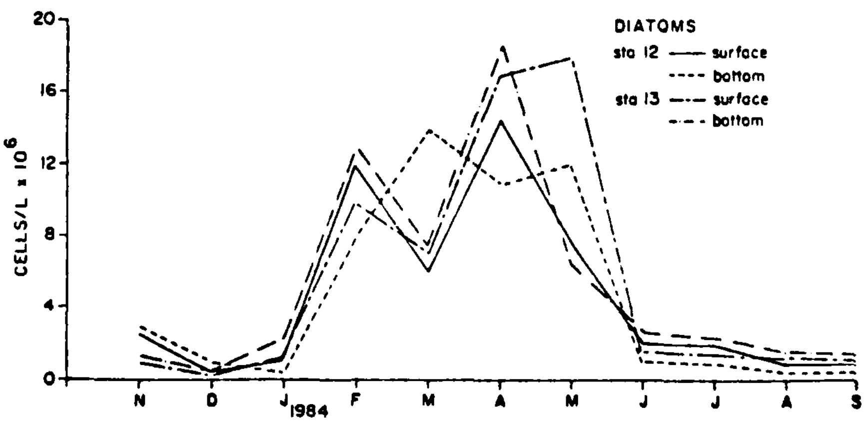


Figure 11.



Figures 9, 10, and 11. Total cell concentrations for diatoms at stations in the study for surface and bottom waters. Total dinoflagellate cell concentrations are also given in Figure 9.

Figure 12.

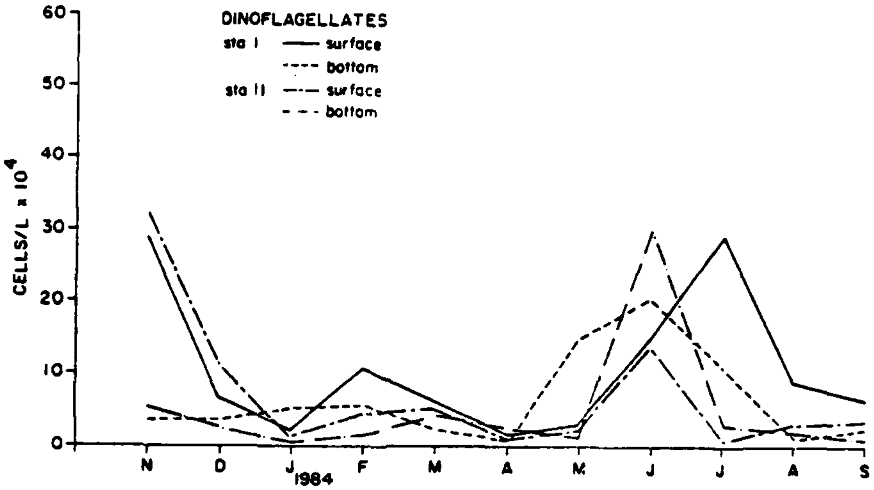
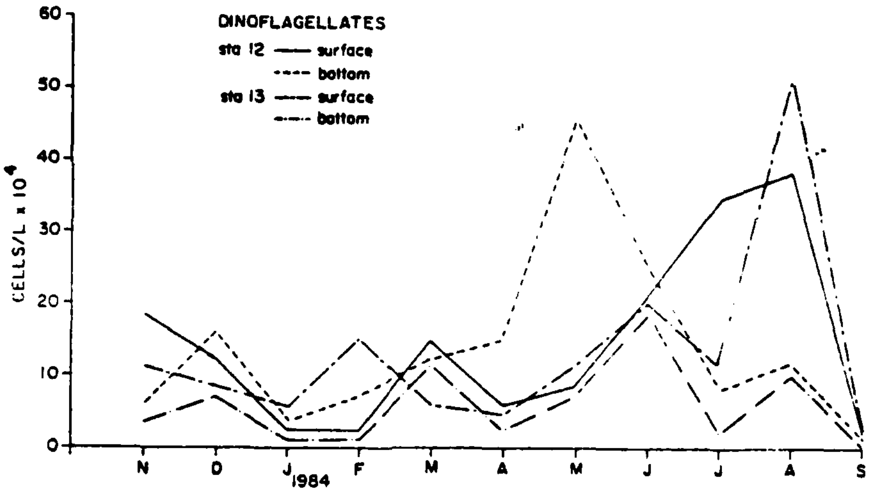


Figure 13.



Figures 12, 13. Total cell concentration for dinoflagellates at stations in the study for surface and bottom waters.

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